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(71) Applicant: **MURATA MANUFACTURING CO., LTD.**
26-10, Tenjin 2-chome
Nagaokakyo-shi Kyoto-fu(JP)

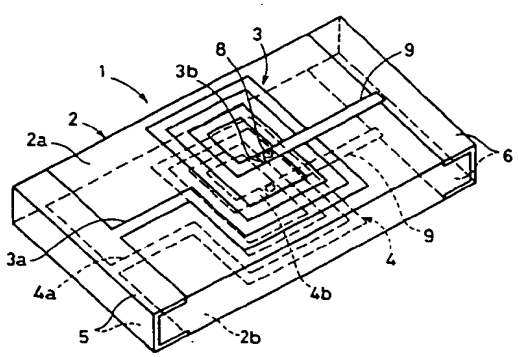
(72) Inventor: **SENDA, Atsuo**
Murata Manufac. Co., Ltd., 26-10, Tenjin 2-chome
Nagaokakyo-shi, Kyoto-fu 617(JP)
Inventor: **KANOU, Osamu**
Murata Manufac. Co., Ltd., 26-10, Tenjin 2-chome
Nagaokakyo-shi, Kyoto-fu 617(JP)
Inventor: **MISAKI, Katsuhiro**
Murata Manufac. Co., Ltd., 26-10, Tenjin 2-chome
Nagaokakyo-shi, Kyoto-fu 617(JP)

(74) Representative: **Schoppe, Fritz, Dipl.-Ing.**
Seitnerstrasse 42
W-8023 Pullach bei München(DE)

(54) **HIGH FREQUENCY COIL AND METHOD OF MANUFACTURING THE SAME.**

(57) A high frequency coil having a structure in which strip-like coil conductors are formed on the surfaces of an insulating substrate, and a method of manufacturing the coil. An object of the invention is to increase the Q value of the coil without increasing the film thickness and wire width of the coil conductors. A pair of coil conductors (3, 4) are so formed that the coil conductors sandwich an insulating substrate (1). The paired coil conductors (3, 4) are so connected in parallel to each other that currents flow through them in the same direction. The ends of the paired coil conductors (3, 4) are connected electrically with an input and an output electrode (5, 6) formed on the insulating substrate (1).

FIG. 1



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FIELD OF THE INVENTION

The present invention relates generally to a high frequency coil having a structure in which strip-shaped coil conductors are formed on the surface of an insulating substrate and a method of fabricating the same, and more particularly, to a high frequency coil whose Q can be increased without increasing the thickness and the line width of coil conductors and a method of fabricating the same.

BACKGROUND OF THE INVENTION

Conventionally, a high frequency coil used in a microwave circuit or the like has had the following structure. More specifically, the high frequency coil has a structure in which a coil conductor, for example, of a spiral type, is formed on the surface of an insulating substrate, an input electrode and an output electrode are respectively formed in side edge portions opposed to each other of the insulating substrate, and the input electrode and the output electrode are electrically connected to an outer end and an inner end of the above coil conductor, respectively. The above described high frequency coil is disclosed in, for example, British Patent Publication GB223624A.

In such a high frequency coil, a coil conductor is formed by a thin film forming technique such as sputtering or vacuum evaporation. Therefore, the high frequency coil has the disadvantage in that the electrical resistance of the coil conductor is increased because the thickness of the coil conductor is not made too large, resulting in decreased Q of the coil. Therefore, attempts have been conventionally made to lower the electrical resistance of the coil conductor by increasing the thickness and the line width of the coil conductor so as to increase Q of the coil.

However, the conventional high frequency coil has the disadvantage in that if the line width of the coil conductor is increased, the substrate is increased in size by the amount of the increase, to make it impossible to meet the recent requirement of miniaturization of electronic components.

Furthermore, if the thickness of the coil conductor is increased, additional time is required to make etching by the amount of the increase. As a result, the high frequency coil has the disadvantage in that there occurs a undesirable phenomenon referred to as under etching.

Consequently, there is a limitation on the decrease in thickness of the coil conductor, so that there is actually a limitation on the improvement in Q of the coil. In addition, it is considered that the thickness of a coil conductor is increased by superimposing on the upper surface of one coil conductor another coil conductor. However, the line width of the coil conductor and the spacing between portions where the coil conductors are wound are very small, i.e., several tens of micrometers, thereby to make it very difficult in the fabrication to further superimpose on one coil conductor another coil conductor having the same size with high precision.

OBJECT OF THE INVENTION

Accordingly, an object of the present invention is to eliminate the above described disadvantages of the conventional high frequency coil and to provide a high frequency coil having a structure in which Q can be increased without increasing the thickness and the line width of coil conductors and a method of fabricating the same.

DISCLOSURE OF THE INVENTION

The inventors of the present application have found that if a plurality of high frequency coils are electrically connected in parallel so as to decrease the conductor resistance of coil conductors, the conductor resistance can be decreased but the inductance is similarly decreased so that Q of the coil cannot be improved.

As the result of further examining a structure in which a plurality of coil conductors are connected in parallel, the inventors have found that the amount of the decrease in conductor resistance is larger than the amount of the decrease in inductance if a pair of coil conductors are formed such that the directions of currents flowing through the coil conductors are the same and so as to be opposed to each other with the insulating layer being interposed therebetween and have found that Q of the coil can be increased because the decrease in inductance can be restrained, thereby to make the present invention.

More specifically, a high frequency coil according to the present invention has a structure comprising at least one insulating layer, a pair of coil conductors formed on both major surfaces of the insulating layer so as to be opposed to each other with the above insulating layer being interposed therebetween, and an input electrode and an output electrode formed on the above insulating layer, in which one end of each of the above pair of coil conductors is electrically connected to the input electrode and the other end thereof is electrically connected to the output electrode such that the directions of currents flowing through the above coil conductors are the same.

Furthermore, the high frequency coil according to the present invention includes one having the following multilayer structure in addition to the

above described structure in which a pair of coil conductors is formed on both major surfaces of one insulating layer. More specifically, the present invention also includes a structure comprising a plurality of insulating layers, in which the insulating layers and pairs of coil conductors are alternately laminated such that the pair of coil conductors is arranged on both major surfaces of each of the insulating layers laminated.

Meanwhile, an insulating layer made of an insulating material having sufficient mechanical strength to support coil conductors, for example, glass or ceramics is generally used as the above described insulating layer. When a plurality of insulating layers are laminated, however, the insulating layers may be made of a flexible insulating material provided that the lowermost insulating layer is made of such a rigid insulating material.

Furthermore, in forming coil conductors according to the present invention, the known thin film forming technique such as a sputtering process, an evaporation process, an ion plating process or a screen printing process can be utilized. That is, a method of forming the coil conductors is not particularly limited.

Additionally, a method of fabricating a high frequency coil according to the present invention comprises the steps of preparing an insulating layer, forming a conductor on the entire surface of the above insulating layer, etching the above conductor to form first and second coil conductors formed so as to be opposed to each other while being separated by the insulating layer and input and output electrodes on both major surfaces of the above insulating layer, coating both the entire major surfaces of the above insulating layer with photosensitive synthetic resin to form photosensitive synthetic resin films, disposing masks on portions, which face the above input and output electrodes and one end of each of the coil conductors, of the above photosensitive synthetic resin films to expose and develop the photosensitive synthetic resin films, removing portions other than the portions of the photosensitive synthetic resin films hardened by the exposure after the development to expose the input and output electrodes and to form a through hole in the portion facing the above one end of each of the coil conductors, and forming a conductor film on the above insulating layer to electrically connect the output electrode to the one end of each of the coil conductors exposed to an inner surface of the above through hole.

In the high frequency coil according to the present invention, a pair of coil conductors is formed so as to be opposed to each other while being separated by an insulating layer, and the directions of currents flowing through the coil conductors are the same. Accordingly, the decrease in conductor resistance is made larger than the decrease in inductance. Consequently, inductance L is relatively increased, as compared with that of the conventional high frequency coil having decreased conductor resistance. In the high frequency coil according to the present invention, therefore, Q of the coil can be increased by the amount of the relative increase in the inductance L.

Accordingly, in the high frequency coil according to the present invention, Q of the coil can be increased without increasing the thickness and the line width of the coil conductors. Consequently, the increase in size of components of the high frequency coil can be avoided, and no undesired phenomena such as under etching occur at the time of the fabrication of the high frequency coil.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic perspective view for explaining a structure of a high-frequency coil according to an embodiment of the present invention;

Figs. 2 (a) to (c) are diagrams for explaining the high frequency coil according to the embodiment of the present invention, where Figs. 2 (a) and (b) are respectively a plan view and a bottom view showing the high frequency coil, and Fig. 2 (c) is a cross sectional view;

Figs. 3 (a) to (e) are cross sectional views for explaining a method of fabricating the high frequency coil according to the embodiment shown in Fig. 1, where Fig. 3 (a) is a cross sectional view showing an insulating substrate used, 3 (b) is a cross sectional view showing a state where a conductive film having a multilayer structure is formed on the entire surface of the insulating substrate, Fig. 3 (c) is a cross sectional view showing a state where a pair of coil conductors and the like are formed by etching, Fig. 3 (d) is a cross sectional view showing a state where insulating films are formed by coating, and Fig. 3 (e) is a cross sectional view showing a state where the insulating films are exposed and developed to form insulating layers and through holes; and

Fig. 4 is a schematic cross sectional view for explaining another embodiment of the present invention.

BEST MODE FOR CARRYING OUT OF THE INVENTION

Embodiments of the present invention will be described with reference to the accompanying drawings.

Figs. 1 to 3 are diagrams for explaining a high frequency coil according to one embodiment of the present invention.

Referring to Fig. 1, a chip-type high frequency coil 1 according to the present embodiment is constructed by pattern formation of spiral-shaped first and second coil conductors 3 and 4 on both major surfaces 2a and 2b of an insulating substrate 2 made of glass or ceramics such as alumina. In addition, an input electrode 5 and an output electrode 6 are formed on both side surfaces of the above insulating substrate 2 in the longitudinal direction. Outer ends 3a and 4a of the above first and second coil conductors 3 and 4 are connected to the input electrode 5. Furthermore, the surfaces of the first and second coil conductors 3 and 4 excluding regions on the input and output electrodes 5 and 6 on both major surfaces of the above insulating substrate 2 are coated with insulating layers 7 made of polyimide or polyamide resin. Through holes 8 are formed in portions, which face inner ends 3b and 4b of the above first and second coil conductors 3 and 4, of the insulating layers 7. In addition, lead electrodes 9 are respectively formed on the upper surfaces of the above insulating layers 7, and one ends of the lead electrodes 9 are respectively connected to the inner ends 3b and 4b of the first and second coil conductors 3 and 4 through the above through holes 8 and the other ends thereof are respectively connected to the output electrode 6.

The above described first and second coil conductors 3 and 4 are so constructed that the directions of currents flowing through the first and second coil conductors 3 and 4 are the same.

A method of fabricating a chip-type high frequency coil 1 according to the present embodiment will be described with reference to Figs. 2 and 3.

(1) A Ti film 10a for improving adhesion to an insulating substrate 2 subjected to mirror polishing is first formed on the entire outer surface of the insulating substrate 2 by a sputtering process. Subsequently, a Ti-Ag film 10b is formed on the surface of the Ti film 10a by a dual sputtering process (simultaneous sputtering process), and an Ag film 10c is further formed on the surface of the Ti-Ag film 10b similarly by the sputtering process, to form a conductor 10 having a three-layer structure (see Figs. 3 (a) and (b)).

(2) Both major surfaces 2a and 2b of the above insulating substrate 2 are coated with masks, which are not shown, designed in shapes corresponding to the shapes of first and second coil conductors and input and output electrodes and then, are subjected to etching processing. Consequently, portions which are not coated with the masks are removed, to form first and second coil conductors 3 and 4 and input and output electrodes 5 and 6. In Fig. 3 (b), each of the coil conductors 3 and 4 and the input and output electrodes 5 and 6 is illustrated for easy understanding such that it is formed of a single layer. The above first and second coil conductors 3 and 4 have such a structure that they are opposed to each other with the substrate 2 being interposed therebetween (see Figs. 2 (a) and (b) and Fig. 3 (c)).

(3) Subsequently, both the entire major surfaces 2a and 2b of the above insulating substrate 2 are coated with photosensitive polyimide resin to form insulating films 7a and dry them (see Fig. 3 (d)). Then, masks are disposed on portions, which face the above input and output electrodes 5 and 6 and inner ends 3b and 4b of the coil conductors 3 and 4, of the insulating films 7a to expose and develop portions other than the portions of the insulating films 7a. Consequently, the exposed portions of the insulating films 7a remain, while the other portions of the insulating films 7a are removed, to form insulating layers 7. Accordingly, the input and output electrodes 5 and 6 are exposed, and through holes 8 are formed in the portions facing the inner ends 3b and 4b of the coil conductors 3 and 4 in the insulating layers 7 (see Fig. 3 (e)).

(4) Finally, conductive films are formed on the upper surfaces of both the above insulating layers 7 by the sputtering process, and lead electrodes 9 are formed in the same manner as the above described step (2) to connect the inner ends 3b and 4b to the output electrode 6. Accordingly, a high frequency coil 1 according to the present embodiment is formed (see Fig. 2 (c)).

Meanwhile, in the above described step (4), when the inner ends 3b and 4b of the coil conductors 3 and 4 are connected to the output electrode 6, a method of connecting the inner ends 3b and 4b and the output electrode 6 by wire bonding using an Au line and fastening them with nylon or adhesives of an epoxy resin system may be adopted.

Description is now made of the function and the effect of the present embodiment.

In the chip-type high frequency coil 1 according to the present embodiment, the first and second coil conductors 3 and 4 are formed on both the major surfaces 2a and 2b of the insulating substrate 2 so as to be opposed to each other with the substrate 2 being interposed therebetween, and the outer ends 3a and 4a of the coil conductors 3 and 4 are connected to the input electrode 5 and the inner ends 3b and 4b thereof are connected to the output electrode 6, thereby to make the direc-

tions of currents flowing through the coil conductors 3 and 4 the same. Accordingly, the conductor resistance can be reduced to approximately half, and Q of the coil can be improved because the decrease in inductance can be restrained. When only one coil conductor is formed on one major surface of an insulating substrate having a thickness of 0.64 mm, the value of Q is 30 (at 400 MHz) if the value of L is 18 nH. On the other hand, in the structure according to the present embodiment, the value of Q is 35 (at 400 MHz) if the value of L is 10.5 nH, thereby to make it possible to improve Q by approximately 15 %.

Furthermore, in the present embodiment, the first and second coil conductors 3 and 4 may be merely formed opposed to each other on both the major surfaces of the insulating substrate 2 by the thin film forming technique. Accordingly, the thickness and the line width of the coil conductors need not be increased unlike the conventional example. Consequently, the increase in size of components can be avoided, and there arise no problems such as under etching.

Accordingly, if the high frequency coil 1 according to the present embodiment is employed when the thickness and the line width of the coil conductors are made as large as possible and the conductor resistance is made smaller to improve Q, a larger effect is obtained.

Although in the above described embodiment, description was made of a case where the first and second coil conductors 3 and 4 are formed with the insulating substrate 2 being interposed therebetween, the present invention may be applied to a multilayer coil constructed by forming one high frequency coil and then, forming an insulating layer in a portion excluding input and output electrodes and forming coil conductors on the upper surface of the insulating layer, or further repeatedly forming insulating layers and coil conductors. More specifically, as shown in Fig. 4, a multilayered high frequency coil may be constructed by further forming an insulating layer 11 and a third coil conductor 12 on a coil conductor 3 formed on the upper surface of one insulating substrate 2. Alternatively, a multilayered high frequency coil having more layers than those in the example as shown in Fig. 4 may be constructed by further laminating insulating layers and coil conductors.

Additionally, although in the above described embodiment, description was made of spiral-type coil conductors by way of example, it goes without saying that the present invention is not limited to the same. For example, the present invention is also applicable to a high frequency coil having Mianda-type coil conductors.

Claims

1. A high frequency coil comprising:
   at least one insulating layer;
   a pair of coil conductors formed so as to be opposed to each other with said insulating layer being interposed therebetween; and
   an input electrode and an output electrode formed on said insulating layer,
   one end of each of said pair of coil conductors being electrically connected to the input electrode and the other end thereof being electrically connected to the output electrode such that the directions of currents flowing through said pair of coil conductors are the same.

2. The high frequency coil according to claim 1, which further comprises a plurality of insulating layers laminated,
   said insulating layers and pairs of coil conductors being alternately laminated such that the pair of coil conductors is arranged on both major surfaces of each of the insulating layers laminated.

3. The high frequency coil according to claim 1, wherein said input electrode and said output electrode are formed so as to cover a pair of side surfaces, which are opposed to each other, of said insulating layer.

4. The high frequency coil according to claim 1, wherein said insulating layer is a rectangular insulating substrate made of an insulating material.

5. The high frequency coil according to claim 1, which further comprises insulating resin layers formed so as to respectively cover said pair of coil conductors.

6. The high frequency coil according to claim 1, wherein a plane shape of the coil conductor is spiral.

7. A method of fabricating a high frequency coil, comprising the steps of:
   preparing an insulating layer;
   forming a conductor on the entire outer surface of said insulating layer;
   etching said conductor to form first and second coil conductors formed so as to be opposed to each other while being separated by the insulating layer and input and output electrodes on both major surfaces of said insulating layer;
   coating on the entire major surfaces of

said insulating layer with photosensitive synthetic resin to form photosensitive synthetic resin films;

disposing masks on portions, which face said input and output electrodes and one end of each of the coil conductors, of said photosensitive synthetic resin films to expose and develop the photosensitive synthetic resin films;

removing portions other than the portions of the photosensitive synthetic resin films hardened by the exposure after the development, thereby to expose the input and output electrodes and to form a through hole in the portion facing said one end of each of the coil conductors; and

forming a conductor film on said insulating layer, thereby to electrically connect the output electrode to the one end of each of the coil conductors exposed to an inner surface of said through hole.

FIG. 1

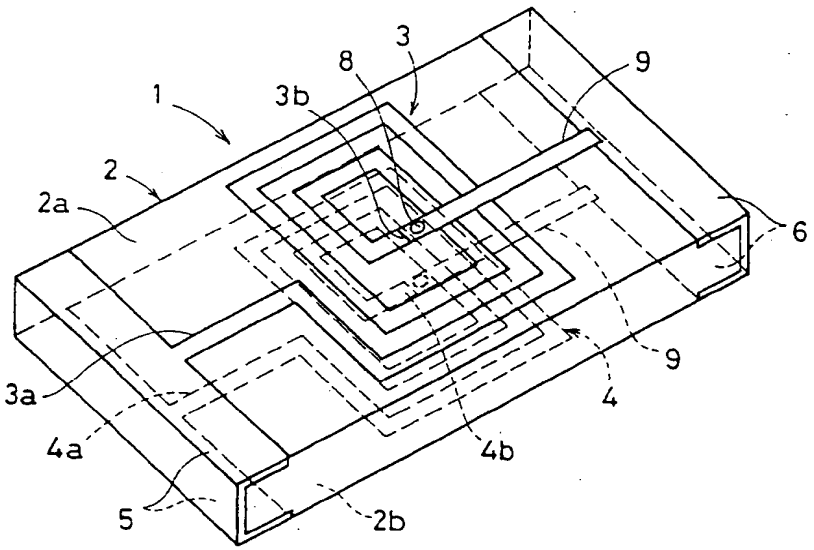


FIG. 2

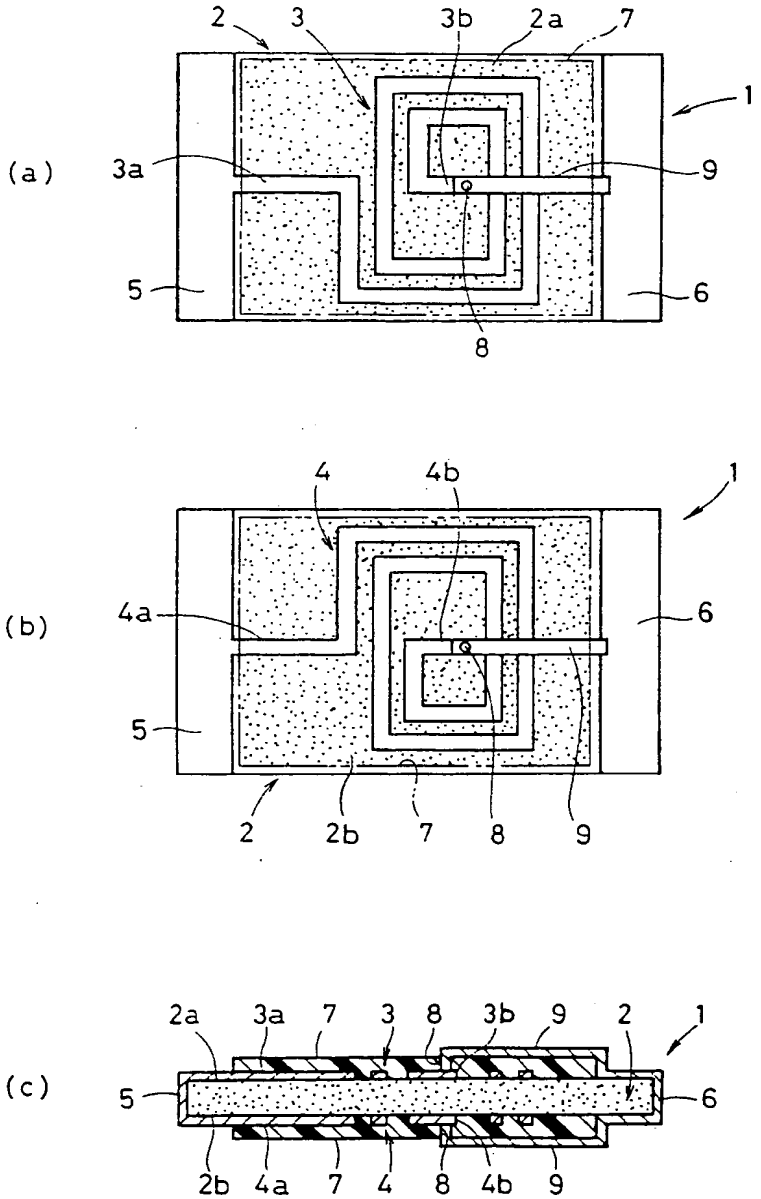


FIG. 3

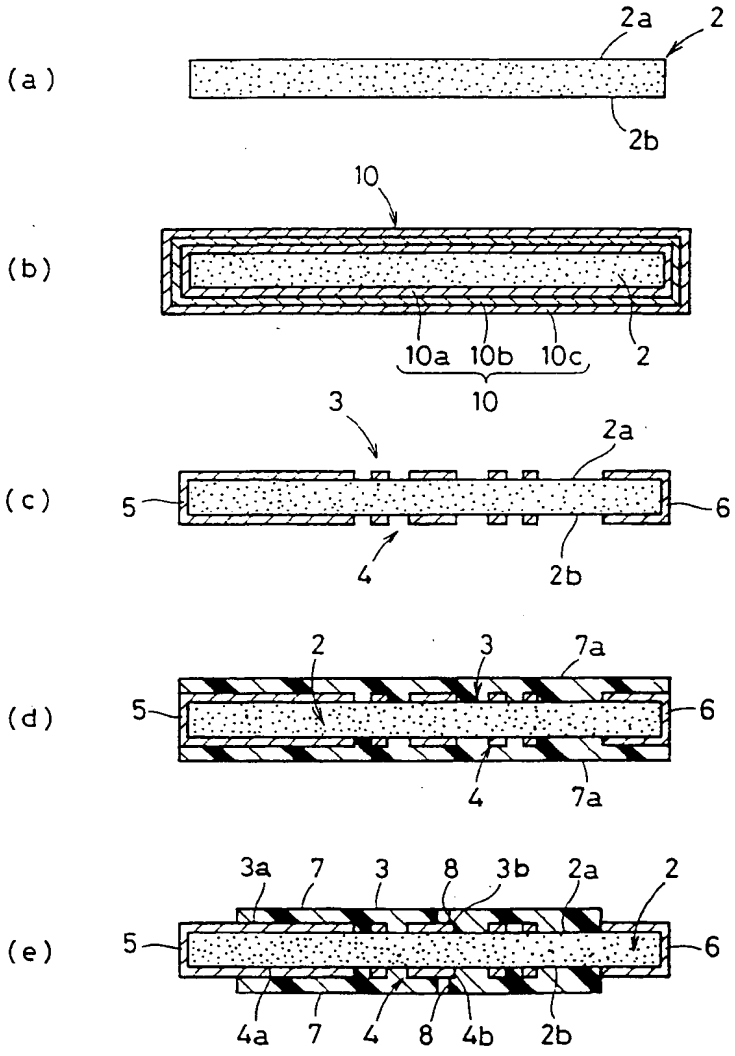
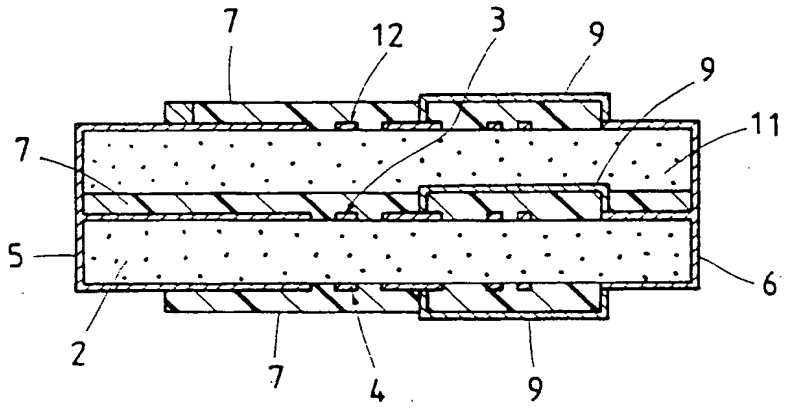


FIG. 4



INTERNATIONAL SEARCH REPORT

International Application No PCT/JP91/00698

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl[5] H01F17/00, H01F41/04

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC	H01F17/00, 19/04, 41/04

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

Jitsuyo Shinan Koho 1971 - 1991
Kokai Jitsuyo Shinan Koho 1971 - 1991

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X,Y	JP, U, 49-101249 (Soshin Denki K.K.), August 31, 1974 (31. 08. 74), Figs. 1 to 3 (Family: none)	1-7
Y	JP, A, 02-123706 (Murata Mfg. Co., Ltd.), May 11, 1990 (11. 05. 90), Columns 7 to 12, Figs. 1 to 4 (Family: none)	3-7

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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"P" document published prior to the international filing date but later than the priority date claimed

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
August 5, 1991 (05. 08. 91)	August 26, 1991 (26. 08. 91)
International Searching Authority	**Signature of Authorized Officer**
Japanese Patent Office	

Form PCT/ISA/210 (second sheet) (January 1985)